CAL Document Change Notification

DCN No. 7650-DCN-0083-01

CHANGE TITLE: -Cal Level Iv Specification, Update To Flight Performance		☒ **Internal**	☐ **External**
ORIGINATOR: J. Eric Grove	**DATE:** 30-Aug-04	**NEXT ASSY:**	

DOC or DWG NUMBER	TITLE	AFFECTED REV.	NEW REV.
LAT-SS-00210	Cal Subsystem Level Iv Specification	03	04

CHANGE DESCRIPTION:

1. Many clarifications of language, many repairs to improper paragraph numbering, throughout.
2. Added verification level to each paragraph.
3. Updated some requirements to testable units and known performance from EM or component-level tests.

REASON FOR CHANGE:

These changes were made to reflect lessons learned from EM assembly and test.

DISPOSITION OF HARDWARE:

☐ **No hardware affected**

☒ **Serial numbers affected:** All CAL Modules

Effective date: 30-Aug-04

	Use as is	Retest	Rework	Scrap	Other/Comment
Raw material	☐	☐	☐	☐	
Parts in process	☐	☐	☐	☐	
Assemblies	☒	☐	☐	☐	

APPROVALS	DATE	OTHER APPROVALS (specify):	DATE
ORIGINATOR: J. Eric Grove	30-Aug-04	**SYSTEMS ENGINEER:** P.V. Dizon	30-Aug-04
SUBSYSTEM MANAGER: W.N. Johnson	30-Aug-04	:	
PROJECT MANAGER: W.C. Raynor	30-Aug-04	:	
QUAL ASSUR. MANAGER: N. Virmani	30-Aug-04	:	
CONFIGURED AND RELEASED: P. Sandora	20-Aug-04		

	Document # LAT-SS-00210-04	Date Effective 31 August 2004
	Prepared by(s) Paolo A. Carosso, J. Eric Grove	Supersedes
GLAST LAT SYSTEM SPECIFICATION	Subsystem/Office Calorimeter Subsystem	
Document Title **LAT CAL Subsystem Specification - Level IV Specification**		

Gamma-ray Large Area Space Telescope (GLAST)

Large Area Telescope (LAT)

Calorimeter (CAL) Subsystem Level-IV Specification

DOCUMENT APPROVAL

Prepared by:

J. Eric Grove *31 August 2004*

J. Eric Grove
CAL Integration and Test Manager

Date

Approved by:

Paul V. Dizon *31 August 2004*

Paul V. Dizon
CAL Mechanical Subsystem Lead Engineer

Date

James Ampe *31 August 2004*

James Ampe
CAL Electrical Subsystem Lead Engineer

Date

Naresh Virmani *31 August 2004*

Naresh Virmani
CAL Quality Assurance Engineer

Date

William C. Raynor *31 August 2004*

William C. Raynor
CAL Project Manager

Date

W. Neil Johnson *31 August 2004*

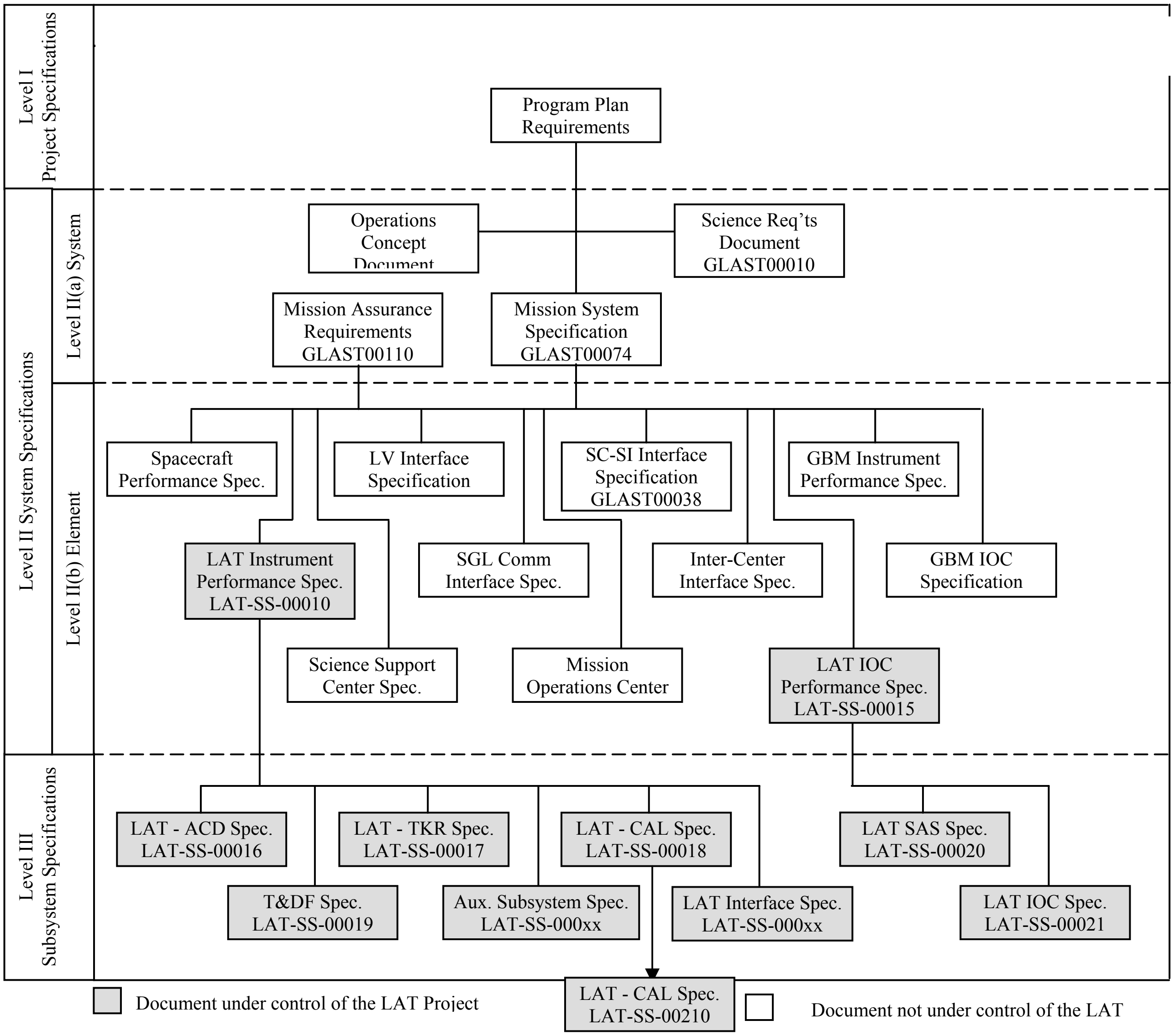
W. Neil Johnson
CAL Lead

Date

CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes	DCN #
1		Initial Release	
2	13 December 01	Section 15 – Verification Matrix	
3			
4	31 Aug 2004	Revised for FM performance	7650-DCN-0083-01

Table of Contents



1 PURPOSE

This document defines level IV subsystem requirements for the GLAST Large Area Telescope (LAT) Calorimeter (CAL).

2 SCOPE

This specification captures the GLAST LAT requirements for the CALORIMETER Sub-system. This encompasses the subsystem level requirements and the design requirements for the CAL as derived from the LAT CAL L-III Subsystem Specification. The verification methods of each requirement are identified.

This specification is identified in the specification tree of Figure 2-1.

2.1 Acronyms

ACD	Anti-Coincidence Detector Subsystem (LAT)
AGN	Active Galactic Nuclei
FOV	Field of View
FWHM	Full Width Half Maximum

GLAST	Gamma-ray Large Area Space Telescope
GN	Ground Network
GRB	Gamma-Ray Burst
IOC	Instrument Operations Center
IRD	Interface Requirements Document
LAT	Large Area Telescope
MC	Monte Carlo
MOC	Mission Operations Center
MSS	Mission System Specification
NRL	Naval Research Laboratory
PI	Principal Investigator
SAS	Science Analysis Software
SDP	Science Data Processing
SI/SC IRD	Science Instrument – Spacecraft Interface Requirements Document
SRD	Science Requirements Document
SSC	Science Support Center
T&DF	Trigger and Data Flow Subsystem (LAT)
TBR	To Be Resolved

2.2 Definitions

γ	Gamma Ray
µsec, µs	Microsecond, 10^{-6} second
A_{eff}	Effective Area
Analysis	A quantitative evaluation of a complete system and /or subsystems by review/analysis of collected data.
Arcmin	An arcmin is a measure of arc length. One arcmin is 1/60 degree.
Arcsec	An arcsec is a measure of lengths of arc. One arcsec is 1/60 arcmin
Background Rejection	The ability of the instrument to distinguish gamma rays from charged particles.
Backsplash	Secondary particles and photons originating from very high-energy gamma-ray showers in the calorimeter giving unwanted ACD signals.
Beam Test	Test conducted with high energy particle beams
cm	centimeter
Cosmic Ray	Ionized atomic particles originating from space and ranging from a single proton up to an iron nucleus and beyond.
Dead Time	Time during which the instrument does not sense and/or record gamma ray events during normal operations.
Demonstration	To prove or show, usually without measurement of instrumentation, that the project/product complies with requirements by observation of results.

eV	Electron Volt
Field of View	Integral of effective area over solid angle divided by peak effective area.
GeV	Giga Electron Volts. 10^9 eV
Higher Level Processing	Processing of level 1 data into science products. Consists of generating exposure calculations, detecting sources, measuring their spectra, determining their time histories, and locating potential counterparts in other astronomical catalogs.
Inspection	To examine visually or use simple physical measurement techniques to verify conformance to specified requirements.
MeV	Million Electron Volts, 10^6 eV
ph	photons
Point Source Sensitivity	The weakest detectable gamma ray source.
s, sec	seconds
Simulation	To examine through model analysis or modeling techniques to verify conformance to specified requirements
sr	steradian, A steradian is the solid (3D) angle formed when an area on the surface of a sphere is equal to the square of the radius of the sphere. There are 4 Pi steradians in a sphere.
Testing	A measurement to prove or show, usually with precision measurements or instrumentation, that the project/product complies with requirements.
Validation	Process used to assure the requirement set is complete and consistent, and that each requirement is achievable.
Verification	Process used to ensure that the selected solutions meet specified requirements and properly integrate with interfacing products.

3 APPLICABLE DOCUMENTS

Documents that are relevant to the development of the GLAST mission concept and its requirements include the following:

LAT-SS-00018 LAT CAL Subsystem Specification – Level III Specification

GE-00010, “GLAST LAT Performance Specification”, August 2000

GLAST00010, “GLAST Science Requirements Document”, P.Michelson and N.Gehrels, eds., July 9, 1999.

GLAST00038, “GLAST Science Instrument – Spacecraft Interface Requirements Document”

GLAST00074, “GLAST Mission System Specification”

GLAST00089, “GLAST Operations Concept”

GLAST00110, “Mission Assurance Requirements (MAR) for Gamma-Ray Large Area Telescope (GLAST) Large Area Telescope (LAT)”

4 GLAST LAT Instrument Concept

The LAT science instrument (SI) consists of an Anticoincidence Device (ACD), a silicon-strip detector tracker (TKR), a hodoscopic CsI calorimeter (CAL), and a Trigger and Dataflow system (T&DF). The principal purpose of the SI is to measure the incidence direction, energy and time of cosmic gamma rays. The measurements are streamed to the spacecraft for data storage and subsequent transmittal to ground-based analysis centers.

4.1 Calorimeter Sub-system

The CAL provides the energy measurement of incident photons and background particles. These measurements, along with the information in the TKR, are used to reconstruct the energy of the incident photons. These CAL measurements are also critical to the background particle identification and rejection. The CAL responds to T&DF requests by digitizing the energy deposition in the CAL and outputs the data to the dataflow system. The CAL also provides fast signals to the T&DF system that report significant energy depositions in CAL. The T&DF system analyzes these fast signals to form requests for data readout of GLAST.

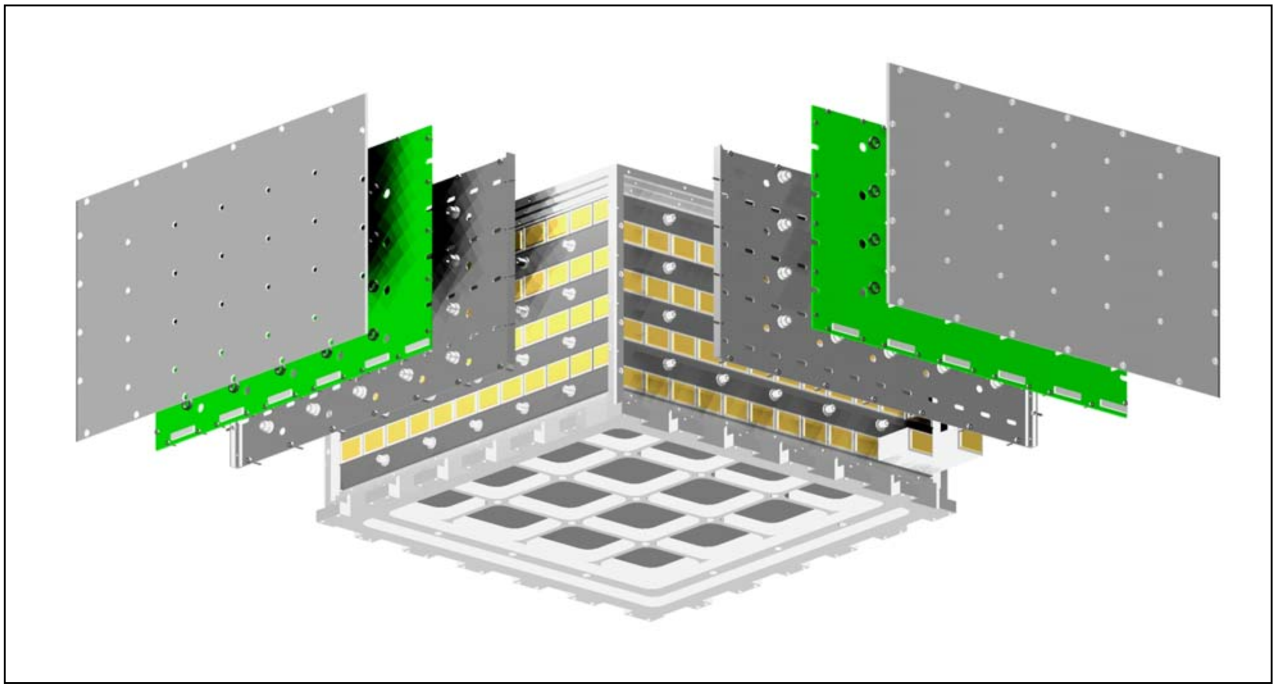


Figure 1: Calorimeter Module exploded view

The CAL subsystem consists of a 4 × 4 array of identical modules. Each module is a hodoscopic array of CsI scintillation crystals and associated readout electronics. Figure 1 shows an expanded view of a single calorimeter module.

4.2 Instrument Responsibilities

The Calorimeter is being developed by a collaboration led by the Naval Research Laboratory (NRL). NRL is responsible for managing the development of the calorimeter subsystem, including Calorimeter design, fabrications, test, and calibration. NRL is responsible to deliver the Calorimeter Modules to SU-SLAC. The responsibilities of the French parties are listed in section 8.4 of the MoA (LAT-MD-XXXXX). The Swedish groups are responsible for the procurement and acceptance testing of the Thallium-doped Cesium Iodide (CsI) as described in MoA document number LAT-MD-00081.

- The institutions responsible for the research teams taking part in the GLAST LAT instrument and forming *the Collaboration*, are hereinafter collectively referred to as *the Collaborating Institutions.* The French institutions involved in the GLAST LAT Calorimeter are Commissariat à l'Energie Atomique / Direction des Sciences de la Matière / Département d'Astrophysique, de Physique des Particules, de Physique Nucléaire et de l'Instrumentation Associée (CEA/DSM/DAPNIA) and Centre National de la Recherche Scientifique / Institut National de Physique Nucléaire et de Physique des Particules (IN2P3) representing the three following laboratories: LPNHE of Ecole Polytechnique and CENBG of Université de Bordeaux. The U.S. institutions involved in the GLAST LAT Calorimeter are the Naval Research Laboratory (NRL) and the Stanford Linear Accelerator Center (SU-SLAC).
- SU-SLAC, operated by Stanford University (hereinafter Stanford), under contract DE-AC03-76SF00515 with the U.S. Department of Energy (DOE), is responsible for management and integration of the LAT instrument. SU-SLAC is the responsible party accountable to the U.S. Department of Energy for the program execution. Stanford University is responsible for the appropriate expenditure of U.S. Government funds.

5 Calorimeter Subsystem Requirements

5.1 General Scientific Performance

5.1.1 Energy Range

[Derived from LAT SS-00010 5.2.1]

The calorimeter subsystem shall support LAT energy measurements of incident photons and charged particles in the energy range 20 MeV to 300 GeV.

This requirement is duplicated from Level III and shall not be verified at Level IV.

5.1.2 Depth of Calorimetry

[Derived from LAT SS-00010 5.2.2]

The calorimeter shall have an active depth of greater than 8.4 radiation lengths of CsI for normally incident particles. The calorimeter shall have adequate depth to contain most of the energy of the gamma-ray showers.

This requirement is duplicated from Level III and shall not be verified at Level IV.

5.1.3 Energy Resolution

The energy resolution shall allow for the measurement of spectral breaks already observed or theoretically predicted from celestial sources. This requirement is defined in Sections 5.1.3.3, 5.1.3.4, and 5.1.3.5.

5.1.3.1 Active Area

[Derived from LAT SS-00010 5.2.2]

The calorimeter subsystem shall provide a projected CsI area of greater than 1050 cm^2 for normally incident particles.

This requirement is duplicated from Level III and shall not be verified at Level IV.

5.1.3.2 Passive Material

[Derived from LAT SS-00010 5.2.2]

Passive material in a calorimeter module (everything not CsI) shall represent no more than 16% of the total mass of the module.

This requirement is duplicated from Level III and shall not be verified at Level IV.

5.1.3.3 On-axis Energy Resolution – Low Energies

[Derived from LAT SS-00010 5.2.2]

The energy resolution (1σ) shall be better than 20% for normal incidence photons for energies in the 20 – 100 MeV range that interact in the calorimeter only. The energy resolution (1σ) shall be less than 10% for photons for energies in the 100 MeV – 10 GeV range.

Note: Low energy measurements require contributing TKR energy loss measurement to achieve specified resolution.

This requirement is duplicated from Level III and shall not be verified at Level IV.

5.1.3.4 On-axis Energy Resolution – High Energies

[Derived from LAT SS-00010 5.2.2]

The energy resolution (1σ) shall be better than 20% for photons, with on-axis incidence, for energies in the 10 – 300 GeV range.

This requirement is duplicated from Level III and shall not be verified at Level IV.

5.1.3.5 Off-axis Energy Resolution – High Energies

[SRD Table 1, #7]

The energy resolution (1σ) shall be less than 6% for photons, with angles of incidence >60 degrees off axis, for energies greater than 10 GeV. The effective area for these off-axis measurements with this energy resolution is expected to be 10 – 20% of the on-axis effective area at energies greater than 10 GeV.

The goal is less than 3%.

This requirement is duplicated from Level III and shall not be verified at Level IV.

5.1.4 Hodoscopic Calorimetry

The calorimeter shall provide imaging capability or physical segmentation to allow the correlation of events in the tracker with energy depositions in the calorimeter.

This requirement shall be verified by Inspection at the Module level.

5.1.5 Operating Modes

[Derived from LAT SS-00010 5.3.5]

The calorimeter shall be capable of operating continuously throughout the orbit. Operating through traversals of the South Atlantic Anomaly shall not damage the calorimeter but, because of the excessive background rates, the acquired data shall not be required to meet performance specifications.

This requirement is duplicated from Level III and shall not be verified at Level IV.

5.2 Modular Calorimeter Subsystem

5.2.1 Components

The calorimeter subsystem shall consist of a 4 × 4 array of identical modules.

This requirement shall be verified by Inspection at the Module level.

5.2.2 Mounting

The calorimeter modules shall be mounted inside the grid matrix of the LAT GRID subsystem.

This requirement shall be verified by Inspection at the Module level.

5.2.3 Structure

The base of the calorimeter modules shall support the mechanical, thermal and electrical interfaces of the LAT T&DF, ACD and power system components.

This requirement shall be verified by Inspection at the Module level.

5.2.4 Hodoscopic

The calorimeter modules shall be hodoscopic arrays of CsI(Tl) scintillation crystals: eight (8) layers of twelve (12) CsI(Tl) scintillation crystals.

This requirement shall be verified by Inspection at the Module level.

5.2.5 PIN Photodiodes

PIN photodiodes shall view each end of the CsI scintillation crystals for measurement of the energy depositions in the crystals.

This requirement shall be verified by Inspection at the Module level.

5.2.6 Crystals

The CsI crystals shall be processed such that the measurements by the PIN photodiodes at the ends of a crystal provide a measurement of the longitudinal position of the energy deposition in the crystal.

This requirement shall be verified by Inspection at the Module level.

5.2.7 Electronics

Each calorimeter module shall include analog and digital readout electronics (AFEE) on the four vertical faces at the ends of the CsI crystal array.

This requirement shall be verified by Inspection at the Module level.

5.3 Calorimeter Module Organization

5.3.1 Module Components

The major components of a calorimeter module shall be a mechanical structure, an array of ninety-six CsI(Tl) detector elements and four analog front end electronics (AFEE) printed wire assemblies.

This requirement shall be verified by Inspection at the Module level.

5.3.2 Module Geometric Area

Each calorimeter module shall provide a projected CsI area of greater than 1050 cm^2 for normally incident particles.

This requirement shall be verified by Inspection at the Module level.

5.3.3 Module Mass

[Derived from LAT SS-00010 5.3.6]

The mass of each calorimeter module shall not exceed 93.25 kg.

This requirement shall be verified by Test at the Module level.

5.3.4 Module Power

[Derived from LAT SS-00010 5.3.10]

The power consumption of each calorimeter module, excluding conditioning, shall not exceed 5.6875 W.

This requirement shall be verified by Test at the Module level.

5.3.5 Command and Data Interface

5.3.5.1 Communication

The calorimeter electronics shall communicate with the Trigger and Data Flow (T&DF) subsystem using LAT standard communications protocols.

This requirement is duplicated from Level III and shall not be verified at Level IV.

5.3.5.2 Data Format

Serial data from the readout electronics shall be merged into a serial message by a tower electronics module (TEM) mounted on the base plate of each module for transfer to the T&DF subsystem.

This requirement shall be verified by Inspection at the Module level.

5.3.5.3 Data Collection

The TEM shall process trigger requests and collect rate and housekeeping monitoring from the CAL AFEE and distribute commands from the T&DF to the AFEE.

This requirement shall be verified by Inspection at the Module level.

5.4 Calorimeter Module Performance

5.4.1 Module Energy Measurement

The energy measurement of the calorimeter modules is defined by the performance at the single crystal level and the muon energy resolution.

5.4.1.1 Single CsI Crystal Energy Measurement Range

The energy measurement range for each of the CsI scintillation crystals shall include the range from 5 MeV to 100 GeV. The goal is to achieve a low energy threshold of 1 MeV.

This requirement is duplicated from Level III and shall not be verified at Level IV.

5.4.1.2 Division of Single Crystal Energy Measurement

The full range of energy measurement in each crystal shall be divided into four sub-ranges, each with approximately one eighth of the dynamic range of the previous.

The highest energy range (“HEX1”) shall span up to the full energy range, nominally 100 GeV. The next highest energy range (“HEX8”) shall span up to ~1/8th of the full range, up to ~12.5 GeV. The next energy range (“LEX1”) shall span up to ~1/64th of the full range, i.e. up to ~1.6 GeV. The lowest energy range (“LEX8”) shall span up to ~1/512th of the full range, i.e. up to ~200 MeV.

This requirement shall be verified by Test at the Module level.

5.4.1.3 Energy Measurement, Integral Linearity

In each of the four energy ranges (LEX8, LEX1, HEX8, and HEX1), the maximum deviation from a linear transfer function between charge injection amplitude and ADC output shall be <2% of full scale.

This requirement shall be verified by Test at the Module level.

5.4.1.4 Energy Measurement, Peaking Time

The LEX8 signal shall peak at 3.5 ± 1 μsec at 20–25C. All LEX8 channels on a single AFEE board shall have the same peaking time ±1 μsec at 20–25 C.

This requirement shall be verified by Test at the Module level.

5.4.1.5 Energy Measurement, Gain Settings

The low energy and high energy gains shall be adjustable over a range of at least a factor of two in eight monotonically increasing steps.

This requirement shall be verified by Test at the Module level.

5.4.1.6 Energy Range Selection

Energy range selection logic shall control which of the four energy measurements made at each CDE end face is selected for inclusion in the event readout. Selection shall be independently determined for each CDE end face. Selection of one or all four ranges shall be permitted.

Range selection discriminators shall test the output of the four ranges to determine which of the ranges have been saturated by the energy deposition in the crystal. Two modes of selection shall be implemented, auto range selection and commanded range selection. In auto range selection mode, the range selection discriminators shall be tested to select the lowest energy range that is not saturated. In commanded range selection, a range selected by command input shall be presented.

This requirement shall be verified by Test at the Module level.

5.4.1.7 Energy Measurement, Range Droop

The range readout order shall not affect the digitized signal amplitude: for a given charge-injection pulse amplitude, the digitized output for any range shall be constant to within 1%, regardless of whether it is read out first or last.

This requirement shall be verified by Test at the Module level.

5.4.1.8 Zero Suppression

The signal from each CDE end face shall be compared with a programmable threshold to identify CsI crystals with measurable energy depositions. The zero suppression level shall be adjustable by command over a range at least as broad as from 20 LEX8-ADC bins above pedestal centroid to 100 LEX8-ADC bins above pedestal centroid.

This requirement shall be verified by Test at the Module level.

5.4.1.9 Measurement Dead Time

[LAT SS-00010 5.2.13]

The dead time associated with the capture and measurement of the energy depositions shall be less than 100 μsec. The goal is less than 20 μsec.

This requirement is duplicated from Level III and shall not be verified at Level IV.

5.4.1.10 Overload Recovery

[Derived from LAT SS-00010 5.2.2, 5.2.13]

The calorimeter electronics shall be capable of recovery from a x1000 overload within 100 μsec. Recovery is defined as below the measurement readout (zero suppression) threshold.

This requirement is duplicated from Level III and shall not be verified at Level IV.

5.4.2 Pedestals

5.4.2.1 Pedestal Noise

The rms width of the pedestal distribution in each of the four energy ranges of each CDE in a Module shall not exceed the limits in Table 1. This measurement shall be made at the nominal gain setting only.

Range	LEX8	LEX1	HEX8	HEX1
Upper limit of pedestal rms (ADC bins)	40	10	40	10

Table 1: Pedestal width, upper limit (in ADC bins)

This requirement shall be verified by Test at the Module level.

5.4.2.2 Pedestal Centroid

The pedestal centroid shall not exceed 1100 ADC bins in any of the four energy ranges at any gain setting.

This requirement shall be verified by Test at the Module level.

5.4.3 Triggering

5.4.3.1 Low Energy Trigger Signal

[Derived from LAT SS-00010 5.2.1, 5.2.3]

The calorimeter shall provide a prompt (within 2 μs of an event) low-energy trigger signal to the LAT trigger system with a detection efficiency of greater than 90% for 1 GeV gamma rays entering the calorimeter from the LAT field of view with a trajectory which traverses at least 6 RL of CsI.

This requirement is duplicated from Level III and shall not be verified at Level IV.

5.4.3.2 Low Energy Trigger Enable/Disable

The low-energy trigger shall be individually enabled or disabled for each CDE end face by command input.

This requirement shall be verified by Test at the Module level.

5.4.3.3 Low Energy Trigger Energy Range

The low energy trigger level shall be individually adjustable by command input. The range of adjustment shall span 50 MeV to 125 MeV. For ground test, at least 90% of GCFEs in a given CAL Module shall allow the low-energy trigger to be set to at least one level between 4 MeV and 12 MeV (the typical cosmic muon energy deposition in a CDE).

This requirement shall be verified by Test at the Module level.

5.4.3.4 High Energy Trigger Signal

[Derived from LAT SS-00010 5.2.1, 5.2.3]

The calorimeter shall provide a prompt (within 2 μs of an event) high-energy trigger signal with a detection efficiency of greater than 90% for 20 GeV gamma rays entering the calorimeter from the LAT field of view that deposit at least 10 GeV in the CsI of the calorimeter.

This requirement is duplicated from Level III and shall not be verified at Level IV.

5.4.3.5 High Energy Trigger Enable/Disable

The high-energy trigger shall be individually enabled or disabled for each crystal end by command input.

This requirement shall be verified by Test at the Module level.

5.4.3.6 High Energy Trigger Energy Range

The high-energy trigger discriminator level shall be individually adjustable by command input. The range of adjustment shall span from 500 MeV to 2.5 GeV.

This requirement shall be verified by Test at the Module level.

5.5 Environmental

The CAL shall be capable of normal operation after being subjected to the environmental conditions given in LAT-SS-00778.

This requirement shall be verified by Test at the Module level.

5.5.1 EMC/EMI

The CAL Module shall be subject to EMC/EMI testing in compliance with levels and configurations specified in LAT-SS-00778.

This requirement shall be verified by Test at the Module level.

5.5.2 Vibration

The CAL Module shall be subject to vibration testing in compliance with levels and configurations specified in LAT-SS-00778.

This requirement shall be verified by Test at the Module level.

5.5.3 Thermal-Vacuum

The CAL Module shall be subject to thermal-vacuum testing in compliance with levels and configurations specified in LAT-SS-00778.

This requirement shall be verified by Test at the Module level.

5.5.4 Component Environment

The CAL components shall be designed to operate in a low Earth orbit environment

This requirement shall be verified by Analysis at the Module level.

5.5.5 Sub-System Environment

The CAL shall be designed to operate in a low Earth orbit environment

This requirement shall be verified by Analysis at the Module level.

5.5.6 SEE Immunity

Critical systems shall be immune to SEEs. Critical systems are those that can cause permanent loss of mission in the event of a single failure

This requirement shall be verified by Analysis at the Module level.

5.5.7 Minimum Power Up Temperature

All electronics shall be able to power up from an initial temperature of –30C and subsequently transition into their other operational modes/states.

This requirement shall be verified by Test at the Module level.

6 Crystal Detector Elements

The Crystal Detector Elements (CDE) include CsI(Tl) crystals, PIN Photodiodes, optical reflective wrap, and PIN interconnection to the AFEE PCB.

6.1 CDE Organization

6.1.1 Module Contents

Each calorimeter module shall contain 96 CDEs.

This requirement shall be verified by Inspection at the Module level.

6.1.2 Crystal

The CDE shall contain a CsI(Tl) crystal shaped as a rectangular parallelepiped with beveled edges and its surfaces treated to control scintillation light yield at the two ends.

This requirement shall be verified by Inspection at the Component level.

6.1.3 Wrap

The CDE shall contain an optical wrap surrounding the CsI crystal to provide the required optical performance.

This requirement shall be verified by Inspection at the Component level.

6.1.4 Dual Photodiode

The CDE shall have a dual PIN photodiode assembly bonded to each end of the CsI crystal.

This requirement shall be verified by Inspection at the Component level.

6.1.5 Interconnect

Two multi-strand wire pairs shall be attached to each PIN photodiode to provide electrical connections with the analog front end electronics board (AFEE).

This requirement shall be verified by Inspection at the Component level.

6.2 CDE Optical Performance

6.2.1 Large Diode Light Yield

The light yield measured by the large PIN photodiode shall be greater than 5000 e-/MeV for energy depositions at the center of the CsI crystal (at time of CDE assembly, room temperature (20 – 25 deg C), measurement techniques as specified in LAT-PS-02571).

This requirement shall be verified by Test at the Component level.

6.2.2 Small Diode Light Yield

The light yield measured by the small PIN photodiode shall be greater than 800 e-/MeV for energy depositions at the center of the CsI crystal (at time of CDE assembly, room temperature (20-25 deg C), measurement techniques as specified in LAT-PS-02571).

This requirement shall be verified by Test at the Component level.

6.2.3 Light Asymmetry with PIN Photodiodes

The change in light asymmetry measure shall be between 0.25 and 0.70 for energy depositions centered at two locations symmetrically placed on the crystal, each 12 cm from the center of the crystal. The asymmetry measure is defined as the ratio (P–M) / (P+M), where P = signal in large diode at the "plus" end and M = signal in large diode at "minus" end.

This requirement shall be verified by Test at the Component level.

6.2.4 Surface Treatment

The crystal end faces shall be roughened in a random pattern to increase the strength of the bond with the photodiode assembly. The long faces shall be treated to achieve the light asymmetry specification with the specified wrapping technique.

This requirement shall be verified Inspection at the Component level.

6.2.5 Wrapping Technique

The crystal shall be wrapped with VM 2000 reflective film. The wrap shall be sufficiently tight that the completed CDE can be inserted into its cell within the mechanical structure. The wrap shall not extend past the ends of the crystal, so that it does not interfere with the positioning of the CDE within its cell. The ends of the crystal shall not be covered with the wrap.

This requirement shall be verified Inspection at the Component level.

6.2.6 Temperature Effects on Optical Performance

The CDE shall meet requirements after exposure to the qualification temperature range.

This requirement shall be verified by Test at the Component level, during the CDE Qualification program.

6.2.7 CDE Spatial Resolution of Energy Deposition

The CDE shall be capable of positioning a Minimum Ionizing energy deposition to less than 1.5 cm (1 σ).

This requirement shall be verified Analysis at the Component level.

6.3 CsI(Tl) Crystal Requirements

Full performance specification for the CDE CsI crystals is in LAT-DS-00095 CsI Cyrstal Specification. The information in this section is for reference only.

6.3.1 Crystal Geometry

The CsI (Tl) crystals shall be rectangular parallelpipeds with a chamfer on the edges of the long dimension. Figure 1 of LAT-DS-00096 shows the mechanical configuration and tolerances for the crystals.

This requirement shall be verified by Inspection at the Component level.

6.3.2 Dimensions

Overall dimensions (mm) of the CsI crystals at 20° C shall be:

Length	326.0 mm
Height	19.9 mm
Width	26.7 mm

The tolerance on dimensions (mm) shall be:

Length	+0.0, –0.6 mm
Height and Width	+0.0, –0.4 mm

This requirement shall be verified by Test at the Component level.

6.3.3 Chamfer

The four 326 mm edges of the crystal shall have a chamfer.

Chamfer length:	0.7 mm, tolerance ± 0.20
Chamfer angle:	45°, tolerance ± 5

This requirement shall be verified by Test at the Component level.

6.3.4 Light Yield Tapering

The CsI crystals shall be processed so that the scintillation light is tapered with position. The tapering shall be monotonic along the crystal and such that with the source 2 cm from one end the light collected at the far end is 60 ± 10 % of the light collected by the PMT close to the source. The tapering shall be determined using PMTs exposed to the full crystal end faces.

This requirement shall be verified by Test at the Component level.

6.3.5 Radiation Hardness

Radiation environment (total radiation dose) shall not reduce light output from the CsI crystals by more than 50% at EOL. After radiation with 10 krad gamma-rays from a Cobalt-60 source, the light yield shall not be reduced by more than 50%.

This requirement shall be verified by sample Test at the Component level.

6.4 PIN Photodiodes

6.4.1 Active Area

The PIN assembly shall hold two PIN photodiodes with a factor-of-6 ratio of active areas.

This requirement shall be verified by Inspection at the Component level.

6.4.2 Spectral Response

The photodiodes shall have spectral response compatible with the scintillation spectrum of CsI(Tl).

This requirement shall be verified by Inspection at the Component level.

6.4.3 Photo Sensitivity

The photodiodes shall have photo sensitivity greater than 0.33 A/W at 540 nm.

This requirement shall be verified by Inspection at the Component level.

6.4.4 Dark Current

The photodiodes shall have dark current of less than 10 nA for the large diode and 3.0 nA for the small diode at 20C.

This requirement shall be verified by Inspection at the Component level.

6.4.5 Terminal Capacitance

The photodiodes shall have terminal capacitance of less than 100 pF for the large diode and 15 pF for the small diode at 1 MHz with 70 V reverse bias.

This requirement shall be verified by Inspection at the Component level.

6.4.6 Physical Dimensions

The photodiode carrier shall be 22.3 (±0.2) mm × 15.0 (±0.2) mm × 1.8 (±0.2) mm.

This requirement shall be verified by Inspection at the Component level.

6.4.7 Active Areas

The small PIN photodiode shall have active area greater than 25 mm^2. The large PIN photodiode shall have active area greater than 150 mm^2.

This requirement shall be verified by Inspection at the Component level.

7 Mechanical / Structure

7.1 CAL Module Mechanical Requirements

CAL Module	Width	Height	Length	Comments
GRID bay nominal dimensions	366.500			
CAL Module stay-clear	364.000	224.300		
CAL Module nominal dimensions	363.000	223.800		
CsI Logs (W x H x L)	26.700	19.900	326.000	Max dims per spec
Baseplate tab thickness		7.000		
CG of CAL above top of baseplate tab		116.000		

Note: Dimensions are in millimeters.

Table 2. Calorimeter Module Geometry Summary

7.1.1 Geometry

The calorimeter module shall comply with the geometry specified in Table 2. The total height of the calorimeter and its mechanical mounting structure shall not exceed 223.8 mm.

This requirement shall be verified by Test at the Module level.

7.1.2 Mechanical Interfaces

The CAL module structure shall provide the mechanical interface to the LAT grid as specified in ICD LAT-SS-00238 and LAT-DS-00233.

The CAL module structure shall provide the nominal positioning, support and mounting interfaces for all subsystem components.

The CAL module structure shall support the Power Supply module and TEM as specified in LAT-DS-00233.

This requirement shall be verified by Inspection at the Module level.

7.1.3 Venting Requirements

In compliance with LAT-SS-00238, the CAL structure shall vent downward, past the bottom plate, not up into the volume between the TKR and the CAL.

This requirement shall be verified by Inspection at the Module level.

7.1.4 Purging Requirements

Purging with dry nitrogen shall be required if the relative humidity of the environment exceeds 50% for 3 hours, or immediately if the RH exceeds 55%.

This requirement shall be verified by Inspection at the Module level.

7.2 CAL Module Structural Requirements

The CAL structure shall provide and maintain the positional integrity of all components that it supports. The structure shall maintain the operational stability of the positions of all instrument components under load.

This requirement shall be verified by Inspection at the Module level.

7.2.1 Structural Stiffness

The CAL structure baseplate is integral to the strength and stability of the LAT GRID. The mechanical structure shall provide a minimum fundamental frequency greater than 100 Hz to a CAL module, isolated from other systems.

This requirement shall be verified by Test at the Module level.

7.2.2 Distortion Under Load

7.2.2.1 Distortion Under Static Load

The CAL mechanical structure shall be able to withstand the different load events without yielding, failing or exhibiting deformations that can influence the performance of the CAL modules or any other system or sub-system. Any point of the mechanical structure shall not displace by more than 0.5mm under a +/-12 g static load, applied along X or Y axis independently, to avoid interaction with the grid walls. Any point of the top of the mechanical structure shall not displace by more than 0.5 mm under a +/- 12 g static load applied along Z axis. To minimize mechanical loads on the TEM boxes, attached below the CAL modules, no point of the bottom plate of the mechanical structure shall displace by more than 0.5mm under a +/- 12 g static load applied along the Z axis.

This requirement shall be verified by Analysis at the Module level.

7.2.2.2 Distortion Under Dynamic Load

The CAL mechanical structure shall be stiff enough in the X and Y directions to keep the difference between the RMS displacements between any two points of the side panels below 0.25 mm, under random vibration with qualification levels. The mechanical structure shall be stiff enough in the Z direction to keep the difference between the RMS displacements between any two points of the top of the structure below 0.5 mm, under random Vibration with qualification levels. The mechanical structure shall be stiff enough in the Z direction to keep the difference between the

RMS displacements between any two points of the bottom plate below 0.25 mm, under random vibration with qualification levels. The levels for random vibration are defined in LAT-SS-00778.

This requirement shall be verified by Analysis at the Module level.

7.2.2.3 Distortion Under Thermal Load

Over a temperature change of 10 degrees C, the mechanical structure shall not distort more than:

0.25 mm between any two points of the side panels

0.5 mm between any two points of the top of the structure

0.25 mm between any two points of the bottom plate

This requirement shall be verified by Analysis at the Module level.

8 Thermal

8.1 Temperature Ranges

The LAT thermal control system shall maintain the CAL components within the operating, test and survival temperatures given in LAT-SS-00778. These temperatures are repeated here for completeness. LAT-SS-00778 shall be the defining document.

Component	Low Temp Limits			High Temp Limits			Survival	
	Qual	AT	Oper	Oper	AT	Qual	Low	High
CAL Module	-30	-20	-15	+30	+35	+50	-30	+50

Table 3: CAL Module temperature ranges

This requirement is levied on the LAT thermal control system.

8.2 Temperature Monitoring

The temperature of each AFEE board shall be monitored by a sensor with an accuracy of ± 0.5C. The temperature of the top plate and bottom plate of the calorimeter shall also be monitored by separate temperature sensors with the same accuracy. There shall therefore be 6 sensors per calorimeter module, or 96 sensors for the entire calorimeter.

This requirement shall be verified by Inspection at the Module level.

9 Analog Front End Electronics

The calorimeter module contains four (4) analog front end electronics (AFEE) printed wiring assemblies, one mounted on each vertical face and attached to the PIN photodiodes on that face. The main components of the AFEE are the GLAST Calorimeter Front End (GCFE) analog ASICs, the analog to digital converters (ADCs) and the GLAST Calorimeter Readout Controller (GCRC) ASICs

9.1 GCFE

The basic functions of the GCFE include charge-sensitive amplification, shaping, multi-range post-amplification, trigger function, track & hold function, and auto-range selection. The key challenges for the ASIC are the large dynamic range and low power dissipation.

The GCFE shall perform spectroscopic measurements over a range from 0.4 MeV to 100 GeV. Each GCFE ASIC shall service one crystal end.

The dynamic range shall be divided into two independent signal chains, one for the low energy range, and one for the high energy range.

This requirement shall be verified by Inspection at the Component level.

9.1.1 Signal Characteristics

The maximum charge delivered to the input of the GCFE ASIC in each gain range shall comply with the following table, under the assumption of the nominal values for light yield in the photodiodes and amplifier ranges.

Range	pC at GCFE Input
LEX8	.16
LEX1	1.3
HEX8	1.6
HEX1	13

This requirement shall be verified by Inspection at the Component level.

Diode	Area (mm^2)	Capacitance (pF)	Leakage (nA at 20C)	Signal (e/MeV)
Low Energy	150	<90	<10	>5000
High Energy	25	<15	<3	>800

Table 4: Characteristics of Dual Photodiode

9.1.2 Low Energy Signal Chain

9.1.2.1 Low Energy Range

A large area (~150 mm^2) PIN photodiode provides the input signal for the low energy range charge amplifier. The low energy charge amplifier shall process energy depositions in the 2 MeV to 1.6 GeV range. The characteristics of the inputs to the low energy range are summarized in Table 4.

This requirement shall be verified by Inspection at the Component level.

9.1.2.2 Low Energy Charge Sensitivity

The low energy range amplifier shall be designed to receive a charge of ~ 5000 e^-/MeV (with time constants defined by CsI(Tl) scintillation constants. These are identified in Table 5.

This requirement shall be verified by Inspection at the Component level.

9.1.2.3 Low Energy Input Capacitance

Exponential Time Constant	Total Charge %
25 ns	2%
700 ns	60%
3.5 μs	40%

Table 5: Relative time constants in CsI(Tl)

The low energy charge amplifier shall meet performance specs when attached to PIN photodiode with capacitance ≤ 100 pF. Performance may be different when the photodiode is not attached.

This requirement shall be verified by Test at the Module level.

9.1.2.4 Low Energy Input Dark Current

The low energy charge amplifier shall meet performance specs when attached to PIN photodiode with dark or leakage current ≤ 10 nA at a temperature of 20C. Performance may be different when the photodiode is not attached.

This requirement shall be verified by Test at the Module level.

9.1.2.5 Low Energy Overload Recovery

The low energy front end shall recover from a ×1000 overload within 500 μsec. Recovery is defined as signal amplitude below the accept or zero-suppression threshold.

This requirement shall be verified by Test at the Component level.

9.1.2.6 Low Energy Gain Adjust

The gain of the low energy channels shall be adjustable by at least a factor of 2 in monotonically increasing steps.

This requirement shall be verified by Test at the Component level.

9.1.3 High Energy Signal Chain

9.1.3.1 High Energy Range

A smaller area (~25 mm^2) PIN photodiode provides the input signal for the high energy range charge amplifier. The high energy charge amplifier shall process energy depositions in the 100 MeV to 100 GeV range. The characteristics of the inputs to the high energy range are summarized in Table 4.

This requirement shall be verified by Inspection at the Component level.

9.1.3.2 High Energy Charge Sensitivity

The high energy range amplifier shall be designed to receive a charge of ~ 800 e^-/MeV with time constants defined by CsI(Tl) scintillation constants. These are identified in Table 5.

This requirement shall be verified by Inspection at the Component level.

9.1.3.3 High Energy Input Capacitance

The high energy charge amplifier shall meet performance specs when attached to PIN photodiode with capacitance ≤ 15 pF. Performance may be different when the photodiode is not attached.

This requirement shall be verified by Test at the Module level.

9.1.3.4 High Energy Input Dark Current

The high energy charge amplifier shall meet performance specs when attached to PIN photodiode with dark or leakage current ≤ 3 nA at a temperature of 20C. Performance may be different when the photodiode is not attached.

This requirement shall be verified by Test at the Module level.

9.1.3.5 High Energy Gain Adjust

The gain of the high energy channels shall be adjustable by at least a factor of 2 in monotonically increasing steps. An additional gain setting shall be used for ground aliveness testing.

This requirement shall be verified by Test at the Component level.

9.1.4 Shaping Amplifiers

The outputs of the charge sensitive preamps shall be shaped with two differing time constants: fast shaping for trigger discriminators and slower shaping for energy measurements. The slow shaped signals of each charge amplifier are each divided into two energy domains.

This requirement shall be verified by Inspection at the Component level.

9.1.4.1 Low Energy Fast Shaper (FLE) Peaking

The low energy fast shaped signals shall peak at 0.5 ± 0.2 μsec.

This requirement shall be verified by Inspection at the Component level.

9.1.4.2 Low Energy Fast Shaper Energy Range

The low energy fast shaping amplifier shall support the lowest ~25% of low energy range, i.e. nominally 400 MeV maximum energy.

This requirement shall be verified by Inspection at the Component level.

9.1.4.3 High Energy Fast Shaper (FHE) Peaking

The high energy fast shaped signals shall peak at 0.5 ± 0.2 μsec.

This requirement shall be verified by Inspection at the Component level.

9.1.4.4 High Energy Fast Shaper Energy Range

The high energy fast shaping amplifier shall support the entire low energy range, i.e. nominally 100 GeV maximum energy.

This requirement shall be verified by Inspection at the Component level.

9.1.4.5 Low Energy Slow Shapers (SLE) Peaking

The low energy slow shaped signals shall peak at 3.5 ± 1 μsec at 20–25C. All ASICs shall have the same peaking time ±1 μsec at 20–25 C.

This requirement shall be verified by Test at the Component level.

9.1.4.6 Low Energy X1 (LEX1) Amplifier

The LEX1 amplifier of the low energy channel shall process the entire low energy charge amplifier range.

This requirement shall be verified by Test at the Component level.

9.1.4.7 Low Energy X8 (LEX8) Amplifier

The LEX8 amplifier of the low energy channel shall process the lowest eighth of the low energy charge amplifier range.

This requirement shall be verified by Test at the Component level.

9.1.4.8 High Energy X1 (HEX1) Amplifier

The HEX1 amplifier of the high energy channel shall process the entire high energy charge amplifier range.

This requirement shall be verified by Test at the Component level.

9.1.4.9 High Energy X8 (HEX8) Amplifier

The HEX8 amplifier of the high energy channel shall process the lowest eighth of the high energy charge amplifier range.

This requirement shall be verified by Test at the Component level.

9.1.5 Track & Hold

Each of the four slow shaped amplifiers (LEX8, LEX1, HEX8, HEX1) shall have track and hold (T&H) circuits designed to hold the peak amplitude of the shaped outputs for amplitude measurements using external ADCs. The timing of the hold signal to capture the peak shall be controlled externally.

This requirement shall be verified by Inspection at the Component level.

9.1.5.1 T&H Tracking

When the hold signal is not active, the T&H circuit shall track the amplitude of the shaped input signal. Thus, adjustment of the hold signal timing relative to the energy deposition shall permit mapping of the pulse shape of the shaper output.

This requirement shall be verified by Inspection at the Component level.

9.1.5.2 T&H Hold

The T&H circuit shall respond to an externally generated hold signal by capturing the amplitude of the shaped signal at the time of the hold. Hold aperture time shall be less than 50 nsec.

This requirement shall be verified by Inspection at the Component level.

9.1.5.3 T&H Droop

The T&H circuit shall be capable of holding a constant signal amplitude for >60 μsec with less than 0.5% droop for a signal amplitude dynamic range of 500.

This requirement shall be verified by Test at the Component level. (It has been restated in units testable at Component level.)

9.1.6 Non-Linearity

In each of the four ranges (LEX8, LEX1, HEX8, and HEX1) the maximum deviation from a linear model shall be <1%.

This requirement shall be verified by Test at the Component level.

9.1.7 Analog Multiplexer

An analog multiplexer shall present one of the four T&H signals to an output buffer for external amplitude measurements with an ADC. The analog multiplexer shall be controlled by energy range selection logic as described in 9.1.7.

This requirement shall be verified by Inspection at the Component level.

9.1.8 Output Buffer

An output buffer shall accept the output of the analog multiplexer and drive the load of an external ADC.

This requirement shall be verified by Inspection at the Component level.

9.1.8.1 Output Buffer Range Adjust

The external buffer shall adjust the voltage range of the analog multiplexer to match the input voltage range of the external ADC.

This requirement shall be verified by Inspection at the Component level.

9.1.9 Energy Range Selection

Energy range selection logic shall control which of the four T&H energy ranges is selected in the analog multiplexer and presented to the output for digitization by the ADC.

This requirement shall be verified by Inspection at the Component level.

9.1.9.1 Range Selection Discriminators

Range selection discriminators shall test the output of the four T&H ranges to determine which of the ranges have been saturated by the energy deposition in the crystal. Saturation is defined as the amplitude at which the input signal enters a non-linear region.

This requirement shall be verified by Inspection at the Component level.

9.1.9.2 Range Selection Readout

The results of the range selection logic, i.e. the multiplexer setting, shall be transmitted to external logic for inclusion in the event readout with the associated ADC value.

This requirement shall be verified by Inspection at the Component level.

9.1.9.3 Auto Range Selection

In auto range selection mode, the range selection discriminators shall be tested to select the T&H output with the lowest energy range (highest gain) that is not saturated and set the analog multiplexer to this T&H output.

This requirement shall be verified by Inspection at the Component level.

9.1.9.4 Commanded Range Selection

In commanded range selection, the selection logic shall use a pre-loaded (via command input) range and set the multiplexer to that T&H output.

This requirement shall be verified by Inspection at the Component level.

9.1.9.5 Sequential Range Selection

In either the auto range or commanded range selection mode, it shall be possible to sample all four T&H outputs in sequence. The sequence shall start at the autoranged or commanded range and increment (modulo 4) through the four ranges. The increasing order shall be LEX8, LEX1, HEX8 and HEX1.

This requirement shall be verified by Inspection at the Component level.

9.1.10 Zero Suppression or Measurement Accept Readout

9.1.10.1 Accept Discriminator

The amplitude of the LEX8 output shall be compared with a programmable threshold – the accept lower level discriminator – to identify CsI crystals with measureable energy depositions. This crystal-accept signal shall be transmitted to external logic for determination of crystals to be included in the event readout message.

This requirement shall be verified by Inspection at the Component level.

9.1.10.2 Accept Discriminator Adjustment

The accept discriminator level shall be adjustable by command to the ASIC over a range at least as broad as from one pedestal rms above pedestal to 100 LEX8 ADC bins above pedestal.

This requirement shall be verified by Test at the Component level.

9.1.11 Trigger Discriminator and Logic

The outputs of the two 0.5 μsec shaping amplifiers (FHE and FLE) are connected to discriminators. The two outputs of the trigger discriminator logic are provided to external logic which forms the calorimeter trigger request inputs to the GLAST trigger system.

This requirement shall be verified by Inspection at the Component level.

9.1.11.1 Trigger Jitter

The variation in time of the leading edge of the trigger output from the time of energy deposition shall be less than ± 0.2 μsec.

This requirement shall be verified by Test at the Component level.

9.1.11.2 Trigger Enables

Each of the two trigger signals shall be individually enabled or disabled by command input to the ASIC.

This requirement shall be verified by Test at the Component level.

9.1.11.3 Low Energy Trigger Discriminator Adjustment

The low energy trigger (FLE) discriminator level shall be adjustable by command input to DACs inside the ASIC. Two adjustment ranges shall be provided: lowest energies (<30 MeV) with <5 MeV step size and moderate energies (<200 MeV) with <15 MeV step size.

This requirement shall be verified by Test at the Component level.

9.1.11.4 High Energy Trigger Discriminator Adjustment

The high energy trigger discriminator level shall be individually adjustable by command input to DACs inside the ASIC. The range of adjustment shall span the range from 500 MeV to 2.5 GeV.

This requirement shall be verified by Test at the Component level.

9.1.12 Calibration System

The GCFE ASIC shall accept a precision calibration voltage from an external DAC as a reference voltage for a calibration charge injection system.

This requirement shall be verified by Inspection at the Component level.

9.1.12.1 Calibration Range

The test charge injection system shall be capable of testing the entire dynamic range of the GCFE ASIC.

This requirement shall be verified by Inspection at the Component level.

9.1.12.2 Charge Shaping

The charge injection system shall provide input signals to the charge amplifier with time characteristics similar to the CsI light collection.

This requirement shall be verified by Inspection at the Component level.

9.1.12.3 Charge Injection

External signals shall cause the injection of charge into the charge amplifiers. Commandable configuration logic shall cause the injection to occur into either or both of the low energy and high energy charge amplifiers.

This requirement shall be verified by Inspection at the Component level.

9.1.12.4 Test Gain on High Energy Charge Amplifier

The high energy charge amplifier shall provide a test gain to be used in ground aliveness tests with cosmic muons. The test gain shall increase the nominal gain by a factor of approximately 10. The test gain configuration is pre-selected by command input to the ASIC.

This requirement shall be verified by Inspection at the Component level.

9.1.13 Configuration Control

The GCFE ASIC operating configuration shall be selected by commands received via serial command system that is compatible with GLAST standard command protocols.

This requirement shall be verified by Inspection at the Component level.

9.1.13.1 Command Address

Each GCFE ASIC shall respond to its own command address, which shall be programmed via input address pins.

This requirement shall be verified by Inspection at the Component level.

9.1.13.2 Command Functions

The GCFE shall decode and recognize predefined command functions and internally route associated command function data to the appropriate configuration register.

This requirement shall be verified by Inspection at the Component level.

9.1.13.3 Configuration Readback

The GCFE shall be capable of reporting its operating configuration to the external data system when requested via configuration readback command requests.

This requirement shall be verified by Inspection at the Component level.

9.1.14 Signal Acquisition Control

The GCFE ASIC shall capture and readout event amplitudes under the control of an external acquisition control timing signal. The external timing shall control the capture of the peak pulse amplitude in the T&Hs, the range selection and readout of the range and crystal accept bits, the selection and readout of sequential ranges, and the final reset of the ASIC to idle, tracking configuration. The timing of this sequence shall be controlled with the external signal; the control logic and decision making shall be internal to the ASIC.

This requirement shall be verified by Inspection at the Component level.

9.1.15 Performance Requirements

The following requirements apply to the signal acquisition by the charge amplifiers, through the shaping amplifiers, track and holds, analog multiplexer and buffer amplifier.

9.1.15.1 Low Energy Equivalent Noise

The equivalent noise (RMS) on the low energy slow shaped signal paths (LEX8, LEX1) shall be less than 2000 e^-.

The equivalent noise (RMS) on the low energy fast shaped signal path (FLE) shall be less than 3000 e^-.

This requirement shall be verified by Test at the Component level.

9.1.15.2 High Energy Equivalent Noise

The equivalent noise (RMS) on the high energy slow shaped signal paths (HEX8, HEX1) shall be less than 2000 e^-.

The equivalent noise (RMS) on the high energy fast shaped signal path (FHE) shall be less than 10000 e^-.

This requirement shall be verified by Test at the Component level.

9.1.15.3 Integral Linearity

The output of the buffer amplifier for each of the four amplifier ranges shall be monotonically increasing with charge input over the top 99.9% of the energy range. The integral non-linearity shall be less than ±0.5% of full scale. This is the deviation of the best fit straight line from the measured amplitudes over the top 99% of the energy range.

This requirement shall be verified by Test at the Component level.

9.1.15.4 Single Range Processing Deadtime

The signal acquisition and processing time for a single energy range shall be less than 100 μsec. The goal shall be 20 μsec.

This requirement shall be verified by Test at the Component level.

9.1.16 Environmental Requirements

9.1.16.1 Operating Temperature Range

The performance specifications of the GCFE ASIC shall be achieved over the operational temperature range.

This requirement shall be verified by Test at the Component level.

9.1.16.2 Storage Temperature Range

The GCFE ASIC shall be capable of meeting its performance specifications after indefinite storage in the temperature range.

This requirement shall be verified by Analysis at the Component level.

9.1.16.3 Qualification Temperature Range

The performance of the ASIC shall be tested over the qualification temperature range of –30 to +50 degrees C. It shall survive testing over this range and meet performance specifications when returned to the operational temperature range.

This requirement shall be verified by Test at the Component level.

9.1.16.4 Radiation Single Event Latchup

The GCFE ASIC shall be insensitive to latchup for LETs < 8 MeV/(mg/cm^2).

This requirement shall be verified by Test at the Component level.

9.1.16.5 Radiation Total Dose

The GCFE ASIC shall meet its performance specifications after a total radiation dose of 10 kRad.

This requirement shall be verified by Test at the Component level.

9.1.17 Mechanical Requirements

9.1.17.1 Mounting

The GCFE ASIC shall be mounted in a quad flatpack carrier with square footprint of size < 15 mm.

This requirement shall be verified by Inspection at the Component level.

9.1.17.2 Height

The GCFE carrier height shall be less than or equal to 3 mm.

This requirement shall be verified by Inspection at the Component level.

9.1.18 Power

The GCFE ASIC power consumption shall be less than 6 mW per CsI crystal end.

This requirement shall be verified by Test at the Component level.

9.2 ADC

The ADC needed for the calorimeter readout needs to be small, fast, low power and of relatively good resolution.

9.2.1 Number of Bits

The ADC shall be a 12 bit ADC.

This requirement shall be verified by Inspection at the Component level.

9.2.2 Differential Non-Linearity

The average differential non-linearity of the ADC shall be less than 0.25 least significant bit.

This requirement shall be verified by Inspection at the Component level.

9.2.3 Integral Non-Linearity

The maximum non-linearity of the ADC shall be 0.5 % of full range.

This requirement shall be verified by Inspection at the Component level.

9.2.4 Speed

The ADC shall perform a full conversion in less than 10 microseconds for all input values.

This requirement shall be verified by Inspection at the Component level.

9.2.5 Input Voltage Range

The ADC shall convert signals between 0 and an applied reference voltage. The applied reference voltage shall be between 2.0 and 3.0 Volts.

This requirement shall be verified by Inspection at the Component level.

9.2.6 Power

The ADC shall use less than 5 mW in quiescent mode and less than 8 mW during conversions.

This requirement shall be verified by Inspection at the Component level.

9.2.7 Mechanical Dimensions

The ADC shall not be taller than 3 mm, and its footprint shall be less than 13mm by 13 mm.

This requirement shall be verified by Inspection at the Component level.

9.2.8 ADC Power Voltage

The ADC shall operate at a voltage of 3.3 Volts.

This requirement shall be verified by Inspection at the Component level.

9.3 GCRC

9.3.1 Functionality

The GCRC shall have functionality to communicate with the Tower Electronics Module and all components requiring communicate on one AFEE board row, consisting of GCFE ASICs, ADCs, and DAC

This requirement shall be verified by Inspection at the Component level.

9.3.2 Power Consumption

The GCRC ASIC shall consume less than 80 mW when operated at 3.3 Volts.

This requirement shall be verified by Test at the Component level.

9.4 AFEE Boards

Each of the four individual AFEE boards per calorimeter module handles the front-end electronics of the crystal ends facing it.

9.4.1 Functionality

Each board shall hold the GCFEs, ADCs, GCRCs, a DAC (digital to analog converter, for calibrations), a temperature sensor and all these components' associated electronics. The AFEE boards shall also support whatever additional electronics or sensors are deemed necessary in the location of the AFEE boards.

This requirement shall be verified by Inspection at the Component level.

9.4.2 Types of AFEE Boards

There shall be two types of AFEE boards, named X boards and Y boards, for the direction of the crystals they service. The two X (Y) boards are then separated in to a –X (–Y) and + X (+Y) board, depending on which side of the calorimeter they service.

This requirement shall be verified by Inspection at the Component level.

9.4.3 Channel Numbers and Layout

Each AFEE board shall service 48 crystal ends. These crystal ends are arranged in 4 layers of 12 crystals. The crystal pitch is ~ 28 mm, the layer pitch is ~ 42 mm. The AFEE layout shall minimize the connection distance between the PIN diode and the GCFE.

This requirement shall be verified by Inspection at the Component level.

9.4.4 PIN Diode Interface

Each crystal end shall connect to the GCFE with two pairs of multi-strand wire fed through a hole in the AFEE board.

This requirement shall be verified by Inspection at the Component level.

9.4.5 Operating Voltages

Each AFEE board is provided with two voltages: one 3.3V voltage to operate the AFEE board itself, and one high voltage in the negative 50-90 volt range to bias the PIN diodes. The regulations of these voltages shall not happen on these boards, but the boards shall filter these voltages appropriately.

This requirement shall be verified by Inspection at the Component level.

9.4.6 TEM Electrical Interfaces

The AFEE board shall communicate to the Tower Electronics Module (TEM) through Low Voltage Differential Signaling (LVDS). No common ground shall span the connection.

This requirement shall be verified by Inspection at the Component level.

9.4.7 Mechanical Dimensions

Each AFEE board shall have maximum dimensions of 341 mm by 341 mm. The maximum thickness of the board shall be 2 mm. The maximum thickness of the board and its components shall be 8 mm. No component shall be raised more than 3 mm from either surface of the board.

This requirement shall be verified by Inspection at the Component level.

9.4.8 Mechanical Interfaces

The mechanical interface and support for each X-side (Y-side) AFEE board shall be compatible with the X-side (Y-side) Closeout Panel, as specified in LAT-DS-00920 (LAT-DS-00921).

This requirement shall be verified by Inspection at the Component level.

9.4.9 Power

Each AFEE board shall not use more than 1.25 Watts of the 3.3V voltage line. Each AFEE board shall not use more than 0.001 Watts of the 50-90 V voltage line.

This requirement shall be verified by Test at the Component level.

9.4.10 Thermal Requirements

9.4.10.1 Operating Temperature Range

The performance specifications of the AFEE shall be achieved over the operational temperature range given in Table 3.

This requirement shall be verified by Test at the Component level.

9.4.10.2 Storage Temperature Range

The AFEE shall be capable meeting its performance specifications after indefinite storage in the temperature range of –20 to +40 degrees C.

This requirement shall be verified by Analysis at the Component level.

9.4.10.3 Qualification Temperature Range

The performance of the AFEE shall be tested over the qualification temperature range given in Table 3. It shall survive testing over this range and meet performance specifications when returned to the operational temperature range.

This requirement shall be verified by Test at the Component level.

9.4.11 Grounding

The AFEE board shall be grounded to the calorimeter structure per LAT document LAT-SS-00272, LAT Grounding and Shielding Plan.

This requirement shall be verified by Inspection at the Component level.

9.4.12 AFEE Failure

Each AFEE board shall be constructed such that an electrical or electronic failure of one board does not affect any of the other three boards of the same calorimeter module, or the two provided voltages.

This requirement shall be verified by Inspection at the Component level.

9.4.13 Coating

Each AFEE board shall be coated with conformal coating per specification LAT-PS-03840.

This requirement shall be verified by Inspection at the Component level.

9.5 CAL Module to T&DF Interface

The AFEE shall interface to the T&DF system using wire bundles that attach the AFEE to the TEM mounted on the CAL baseplate.

This requirement shall be verified by Inspection at the Component level.

10 Data System

The Calorimeter Data System functionality shall reside in the Calorimeter Controller, located in the Tower Electronics Module.

This functionality and the CAL AFEE to TEM interface requirements are specified in LAT-SS-00467.

This requirement shall be verified by Inspection at the Component level.

11 Operational Modes

The Calorimeter shall provide the functionality required for the SI to perform operations in the sky survey, pointed observation and safe modes of operation. These specific requirements can be found in the GLAST Mission System Specification (MSS), Section 3.1.15, Modes of Operation. The Calorimeter shall meet the load shedding requirements of the fault protection functions on the spacecraft that are identified in the SI/SC IRD, Section 3.2.7, Fault Protection.

This requirement shall be verified by Inspection at the Component level.

12 Ground Support Equipment

12.1 Stand-Alone Testing

CAL modules shall have ground-support equipment that will allow for stand-alone operation, test and data analysis.

This requirement shall be verified by Inspection at the Module level.

12.2 Simulators

CAL module GSE shall be supported by TEM and T&DF simulators provided by the T&DF subsystem designers.

This requirement shall be verified by Inspection at the Module level.

12.3 Computer and Network

Workstations or personal computers associated and provided with the CAL subsystem shall have Ethernet connectivity with appropriate software to share data files and electronic messages with other nodes on the I&T local area network

This requirement shall be verified by Inspection at the Module level.

12.4 Pre-Integration Testing

All module components shall undergo functional, environmental and interface testing prior to module integration and test in order to verify their individual functional and performance requirements.

This requirement shall be verified by Analysis at the Module level.

13 Integration and Test

13.1 Integration and Test Temperature Range

The Calorimeter shall be capable of tolerating temperatures of 20-25^{o}C in air, in any operational mode. This is the expected temperature range of the controlled environment in the integration and test facilities.

This requirement shall be verified by Analysis at the Module level.

13.2 Integration and Test Relative Humidity

The Calorimeter shall be capable of tolerating relative humidity in the range 35%-50%, in any operational mode. This is the expected humidity range of the controlled environment in the integration and test facilities.

This requirement shall be verified by Analysis at the Module level.